

Excavation, habitation and transportation of massive corals by the crab *Actumnus setifer* (Crustacea: Brachyura: Pilumnidae) in Moreton Bay, Queensland

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ABSTRACT

Previously unreported coral-carrying, and coral-burrowing, behaviour is described and illustrated for *Actumnus setifer* from Moreton Bay, Queensland, Australia. *A. setifer* typically inhabits excavated burrows in living or dead massive coral clumps that weigh as much as one kilogram or more. Records of this behaviour in other species are discussed. Taxonomy is briefly reviewed and full synonymy and distribution records presented. Morphological modifications that allow such behaviour may be important in generically revising the genus *Actumnus*. The sheltered coral reefs of Moreton Bay provide an ideal environment for this crab-coral association to flourish. □ *symbiosis, mutualism, Actumnus, behaviour, coral reef, taxonomy.*

An interesting commensal association between crabs of the genus *Actumnus* and a variety of corals, whereby the crab excavates a burrow in the base of the coral clump and moves the coral from place to place, has been reported several times. Ward (1942) first noted this behaviour for *Actumnus antelmei* Ward, 1942, inhabiting dead corals at Mauritius, while also mentioning that he had seen a similar species behaving in the same way at Lindeman Island, on the Great Barrier Reef, using living colonies of *Leptastrea bottae*, and on reefs off Papua. Later, Lamberts & Garth (1977) reported *A. antelmei* and *A. digitalis* (Rathbun, 1907) inhabiting 12 species of both living and dead corals at Tutuila, American

Samoa. Marsh (1990) also reported an unidentified Xanthoid crab found in a species of *Cyphastrea* coral at Shark Bay, Western Australia, that in all likelihood would also have been an *Actumnus* species.

Actumnus setifer (de Haan, 1835) has a widespread Indo-West Pacific distribution, and a bathymetric range generally < 50 m (Sakai 1976). Although it is commonly associated with coral reef environments it has not been previously recorded as inhabiting a moveable coral shelter. Its habitat has been previously noted as holes made in soft stones (Lanchester 1900), rock or coral crevices, amongst algae and in holes in sponges (Sakai 1976). We here describe and illus-

trate previously unreported coral-burrowing and coral-carrying behaviour of *A. setifer* observed in Moreton Bay, Australia.

Moreton Bay lies at latitude 27°25' S. It is 150 km long (north to south) and about 15 km wide at the northern end where it opens to the South Pacific Ocean. It is enclosed on its eastern margin by large islands of Pleistocene and Holocene dune sands. The southern bay is congested with low deltaic mangrove islands, and high islands of similar lithology to the adjacent mainland occur in the central Bay. In the more open, northern parts of Moreton Bay, coral reefs have developed adjacent to the mainland and several of the islands. Many areas of these reefs have degraded during the late Holocene period, probably as a result of diminished tidal flushing, the changed position of the Brisbane River mouth, and a slight fall in relative sea level (Lovell 1989; Stephens 1992; Johnson & Neil 1998) and, more recently, due to increased sediment concentrations in the Brisbane River due to land use change (Neil 1998). Reefal environments of Moreton Bay have also been exploited for lime-making for more than a century (Allingham & Neil 1995).

TAXONOMY

Family Pilumnidae Samouelle, 1819

Actumnus Dana, 1851

Actumnus Dana, 1851: 128. Type species: *Actumnus tomentosus* Dana, 1852, by subsequent designation of Rathbun (1922); gender masculine [= *Actumnus setifer* (De Haan, 1835)].

Remarks. The genus currently includes 28 species (see Ng *et al.* 2008).

Actumnus setifer (de Haan, 1833)

(Figs 1, 3)

Cancer (Xantho) setifer de Haan, 1833: pl. 3, fig. 3; Yamaguchi, 1993: 580.

Cancer (Pilumnus) setifer — de Haan, 1835: 50.

Actumnus tomentosus Dana, 1852: 243; 1855: pl. 14, fig. 2a–c; Milne-Edwards A., 1865: 285; 1873: 194; Haswell, 1882: 73; Alcock, 1898: 202; Borradaile, 1902: 249; Nobili, 1906b: 132; Grant & McCulloch, 1906: 17; Klunzinger, 1913: 271; Rathbun, 1924: 20.

Actumnus setifer — Milne-Edwards, A., 1865: 287, pl. 15, fig. 5; Richters, 1880: 148; Miers, 1884: 225; de Man, 1887a: 47; Walker, 1887: 110; de Man, 1887b:

262; Pocock, 1890: 74; Henderson, 1893: 364; Ortmann, 1893: 474; 1894: 52; Alcock, 1898: 202; Calman, 1900: 19; Lanchester, 1900: 742; 1902: 541; Borradaile, 1902: 249; de Man, 1902: 639; Nobili, 1906a: 285; Grant & McCulloch, 1906: 17; Rathbun, 1910: 357; 1911: 230; 1914: 660; 1923: 126; Klunzinger, 1913: 272; Balss, 1922: 119; 1924: 20; 1933: 38; Yokoya, 1933: 187; Sakai, 1934: 309; 1935: 70; 1936: 173, pl. 52, fig. 1; 1936: 67; 1939: 528, pl. 65, fig. 1; 1965: 156, pl. 76, fig. 6; 1976: 496, pl. 177, fig. 2; Shen, 1940: 72, 87; Stephensen, 1945: 143; Miyake, 1961: 173; Takeda & Miyake, 1969: 115, fig. 9d–f; Campbell & Stephenson, 1970: 285, fig. 46; Takeda & Nunomura, 1976: 76; Yamaguchi *et al.*, 1976: 38; Takeda, 1977: 86; 1989: 166; 1997: 246; Miyake, 1983: 133, pl. 45, fig. 1; Dai & Yang, 1991: 369, fig. 179(1), pl. 49(7); Yamaguchi & Baba, 1993: 454, fig. 170; Wada, 1995: 402, pl. 112, fig. 1; Muraoka, 1998: 45.

Actumnus setifer var. *tomentosus* — Laurie, 1906: 408; 1915: 458.

Actumnus setifer var. *setifer* — Laurie, 1906: 409.

?*Actumnus setifer* — Barnard, 1947: 365; 1950: 271, fig. 50.

Material Examined. QM-W28544, male (24.0 × 17.0 mm), 2 females (18.3 × 13.2; 21.3 × 14.8 mm), Wellington Point, Moreton Bay, SE Qld, 27°28'0" S, 153°14'0" E, low intertidal, P. Davie, I. Fellegara, 30 Jul 2008, under and in dead coral colonies of *Favia speciosa*. QM-W16680, ovig. female (17.5 × 12.2 mm), King Reef, off Kurrimine Beach, NE Qld, 17°45'0" S, 146°9'0" E, trawled, K. Lamprell, 29.07.1983. QM-W21176, female (11.8 × 9.0 mm), Long Is, Vansittart Bay, Kimberley Coast, WA, 13°58' 9" S, 126°19' 6" E, J.W. Short, 24.11.1995. W27453, 3 males (22.0 × 16.8, 22.4 × 17.1, 22.6 × 17.4 mm), Mirs Bay, New Territories, Hong Kong, 22°55'0" N, 114°40' 0"E, agassiz trawl, P. Davie, 26.04.1989.

Diagnosis. Deep-bodied crab; dorsal surface convex, regions clearly defined; carapace covered with short-cropped tomentum; frontal lobes markedly deflexed; anterolateral margins convex, with three pointed teeth behind exorbital angle, more or less obscured by tomentum; postero-lateral borders markedly excavated, forming concavity into which last pair of ambulatory legs fold. Chelipeds markedly unequal; covered with dense short tomentum; carpus and propodus covered with irregular beaded granules projecting through tomentum. Ambulatory legs relatively short and stout; anterior and posterior borders thickly fringed with setae.

Distribution. Type locality Japan. Widespread from South Africa to Japan and French Polynesia. AUSTRALIA — Albany Passage (Haswell, 1882), Thursday I., Port Denison, Percy Islands and

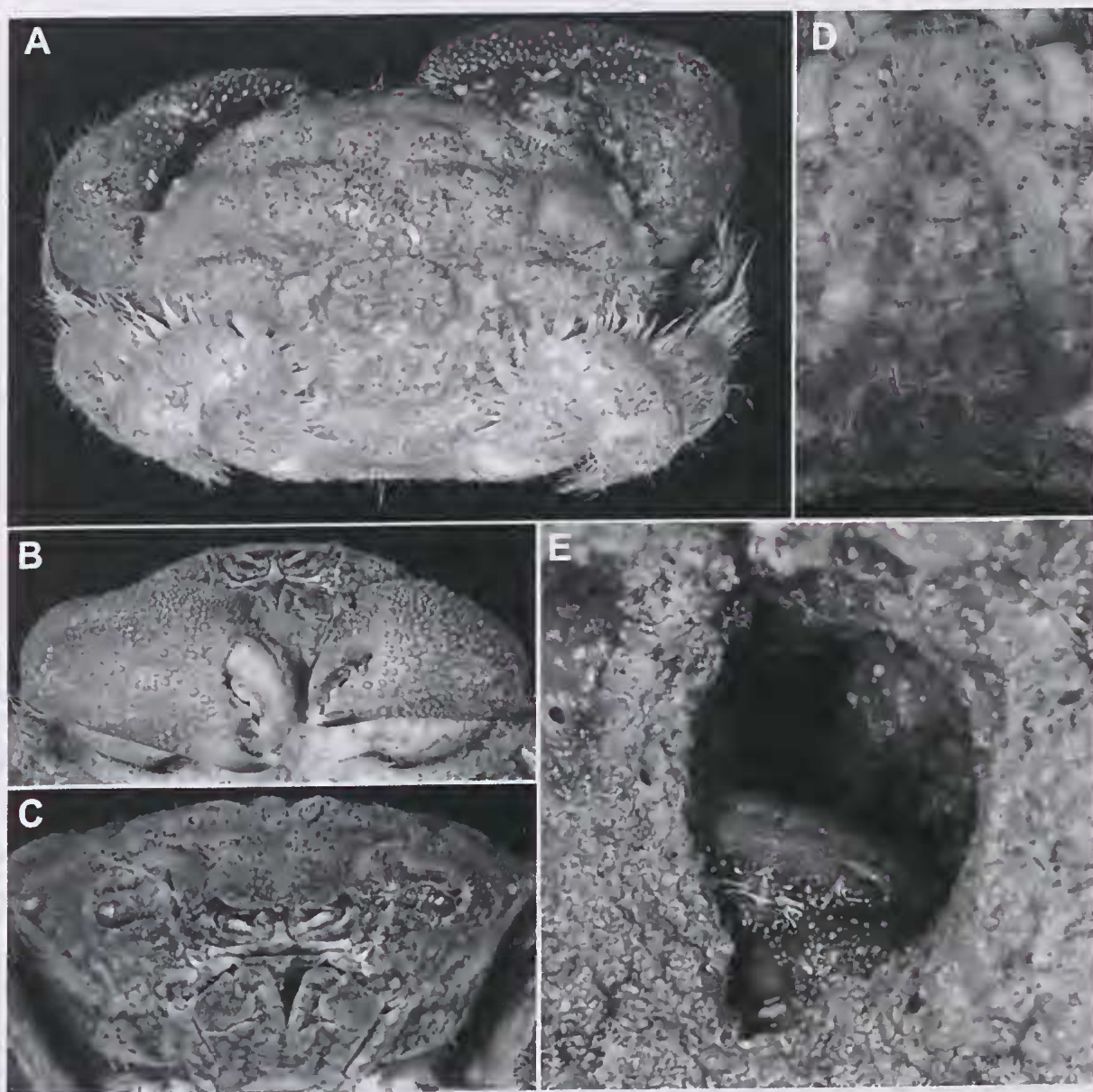


FIG. 1. *Actumnus setifer* male (24.0 x 17.0 mm) from Wellington Point, Moreton Bay (QM-W28544). A, dorsal view with legs folded against body in typical fashion; B, frontal view of claws; C, view of frontal margin, orbits and pterygostome; D, male abdomen and sternum; E, peering out from inside coral hole.

Sir C. Hardy's Is, Qld (Miers, 1884), Thursday I. (Ortmann, 1894), Torres Strait (Calman, 1900), Masthead I. (Grant & McCulloch, 1906), Shark Bay, WA (Miers, 1884, Balss, 1933), Monte Bello Is (Rathbun, 1914), Cape Jaubert (Rathbun, 1924), north-west of Cape Jervis and Kangaroo Island, SA (Rathbun, 1923), Moreton Bay (Campbell & Stephenson, 1970). ELSEWHERE — New Caledonia (A. Milne-Edwards, 1873, Takeda & Nuno-

mura, 1976); Vanuatu (Miers, 1884); Fiji (Miers, 1884); Samoa (Ortmann, 1893, Alcock, 1898); Tahiti (A. Milne-Edwards, 1865); Tahiti or Samoa (Dana, 1852); Red Sea (Klunzinger, 1913, Laurie, 1915); Zanzibar (Nobili, 1906); ? South Africa (Barnard, 1947); Seychelles (Rathbun, 1911); Mauritius (Richters, 1880); Persian Gulf (Alcock, 1898, Nobili, 1906, Stephensen, 1945); India (Alcock, 1898); Sri Lanka (Alcock, 1898, Laurie,

1906); Maldives (Borradaile, 1902); Burma (Alcock, 1898), Gulf of Martaban (Henderson, 1893); Andaman Islands (Alcock, 1898); Mergui Archipelago (de Man, 1887a, Alcock, 1898); Japan (de Haan, 1833; Ortmann, 1893; Calman, 1900, Sakai, 1965; Balss, 1922; Yokoya, 1933; Sakai, 1935; Sakai, 1939; Miyake, 1961; Takeda & Miyake, 1969; Sakai, 1976; Yamaguchi et al., 1976; Takeda, 1977; Miyake, 1983; Takeda, 1989; Takeda, 1997); China (Alcock, 1898; Shen, 1936, 1940; Dai & Yang, 1991); Macclesfield Bank (Pocock, 1890); Gulf of Thailand (Rathbun, 1910); Singapore (Walker, 1887); Malay Peninsula (Lanchester, 1902); Philippines (Miers, 1884); Indonesia (de Man, 1887b; de Man, 1902).

Bathymetric range. Low tide pools to 200 m.

Remarks. This species was first reported from Moreton Bay by Campbell & Stephenson (1970), though their specimen was collected from a dredge and no coral association was recorded. The present specimens were compared with those from other localities in northern Australia, and from Hong Kong (see Material Examined). All Australian specimens conform closely with the Asian crabs, and there is no doubt of their correct identity. Indeed this species has been reported many times from a wide range of localities and only the identity of a specimen from South Africa reported by Barnard (1950) is currently in question — according to Sakai (1965), this specimen differs in the formation of the front, and in the armature of the anterolateral borders.

Actumnus contains 28 currently recognised species (see Ng *et al.* 2008), however there is some suggestion that the genus is not monophyletic as presently conceived (Takeda & Miyake 1969; P. Davie pers. observ.). Clark & Ng (2004) have also documented the complete larval development of *Actumnus setifer*. This species has only three zoeal stages instead of the more common four, and the zoeas differ from those of the only other species of *Actumnus* for which larvae are known, *A. squamosus*, in several carapace and abdominal features. Clark & Ng consider the differences important enough to indicate that the two species are not congeneric.

Actumnus is in need of a thorough taxonomic revision, and as part of this, it will be important to take into account the morphological and

behavioural apomorphies that have evolved in several species in relation to their association with coral. While this association has only been documented for three species thus far, *viz.* *A. antelmei*, *A. digitalis* and *A. setifer*, it can be expected that other species with similar morphology will also prove to inhabit corals. In particular, characters such as the short stout legs with the last pair folding into the deeply excavated posterolateral margins, and the powerful claw morphology that allows these crabs to abrade holes in the coral bases, must be of generic significance. In this context it seems likely that species such as *Actumnus elegans* De Man, 1888, *A. granotuberosus* Garth & Kim, 1983, *A. intermedius* Balss, 1922, *A. margarodes* MacGilchrist, 1905, and *A. similis* Takeda & Miyake, 1969, amongst others, will need to be transferred into one or more new genera.

BEHAVIOUR & ECOLOGY

PRESENCE OF *A. SETIFER* IN MORETON BAY

Prior to this study, Campbell & Stephenson (1970) reported a single specimen of *A. setifer* in a dredge sample from south of Peel Island. Our observations of *A. setifer* in Moreton Bay were made at Mud, Green, Coochiemudlo, Peel, Bird and Goat Islands, at Dunwich and Myora on North Stradbroke Island, and at Wellington Point and Scarborough on the mainland side of the Bay (Fig. 2). All of these sites represent coral reefs except for Dunwich and Myora, where there are extant coral communities, and Scarborough where no live corals were observed.

Searches were made using viewing buckets, manta tows, snorkelling, wading and observations from a boat in < 1 m water depth.

A. setifer was most commonly found in colonies of *Favia speciosa*, the most common coral species in Moreton Bay, but also occurred in other massive corals (*Favia*, *Favites*, *Goniopora* and *Cyphastrea* sp.), both living and dead. *F. speciosa* has not previously been reported as having such a relationship with crabs. Coral use by *A. setifer* appeared to be roughly proportional to the coral species' relative abundance, although this relationship was not quantified. Other coral morphologies are found in Moreton Bay (eg. branching, tabulate, foliose, encrusting), however *Actumnus* crabs were never observed utilising

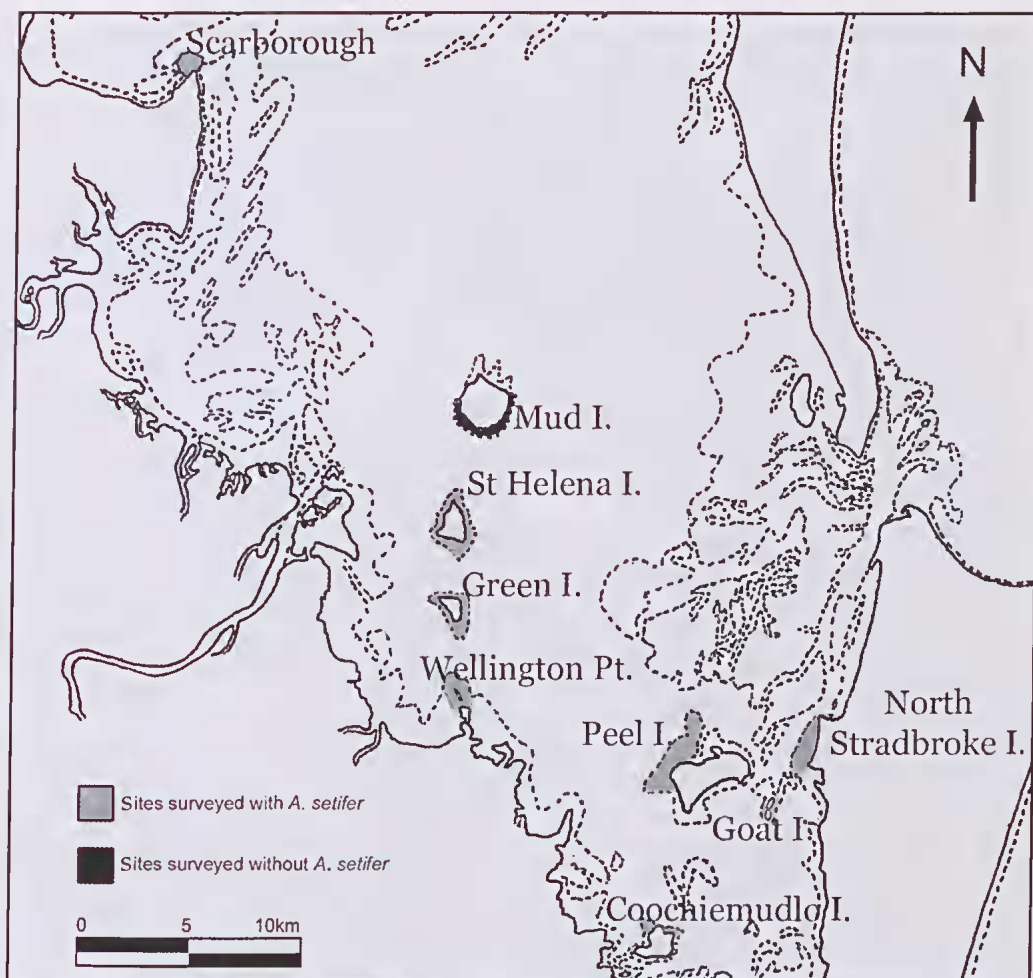


FIG. 2. Localities where coral-carrying *Actumnus setifer* have been observed in Moreton Bay.

coral colonies with morphologies other than massive.

A. setifer was predominantly found in areas of Moreton Bay proximal to living and dead coral reefs. The substrate in these areas was a sparse cover of massive corals and/or coral debris on patches of sandy or muddy sediments. These areas are consistent with the ecotone habitat of *Actumnus* crabs at Tutuila (Lamberts & Garth 1977). Areas of the Mud Island reef flat which were searched did not support the *A. setifer* coral association, while all other reefal areas searched did. Coral dredging of the Mud Island reef flat has created a substrate of loose rubble and steep slopes (Allingham & Neil 1995). This substrate would inhibit the movement of corals carried by crabs and also inhibit feeding by the

crabs, thereby excluding the *A. setifer* coral association from such sites.

BEHAVIOUR

Actumnus setifer observed in a salt water aquarium showed patterns of behaviour similar to those of the *Actumnus* crabs observed by Lamberts & Garth (1977). If the colony was overturned, the crab would roll it back so that the entrance to the burrow faced the substrate (see sequence of photographs in Fig. 3). Movement of the colonies was in small jerks, as the crab gripped the coral colony with the last pair of legs and pushed against the substrate with its chelipeds.

The burrows of *A. auteluei* and *A. digitalis* are excavated by the crab using the trabeculated manus of its chelipeds as a rasp (Ward 1942;

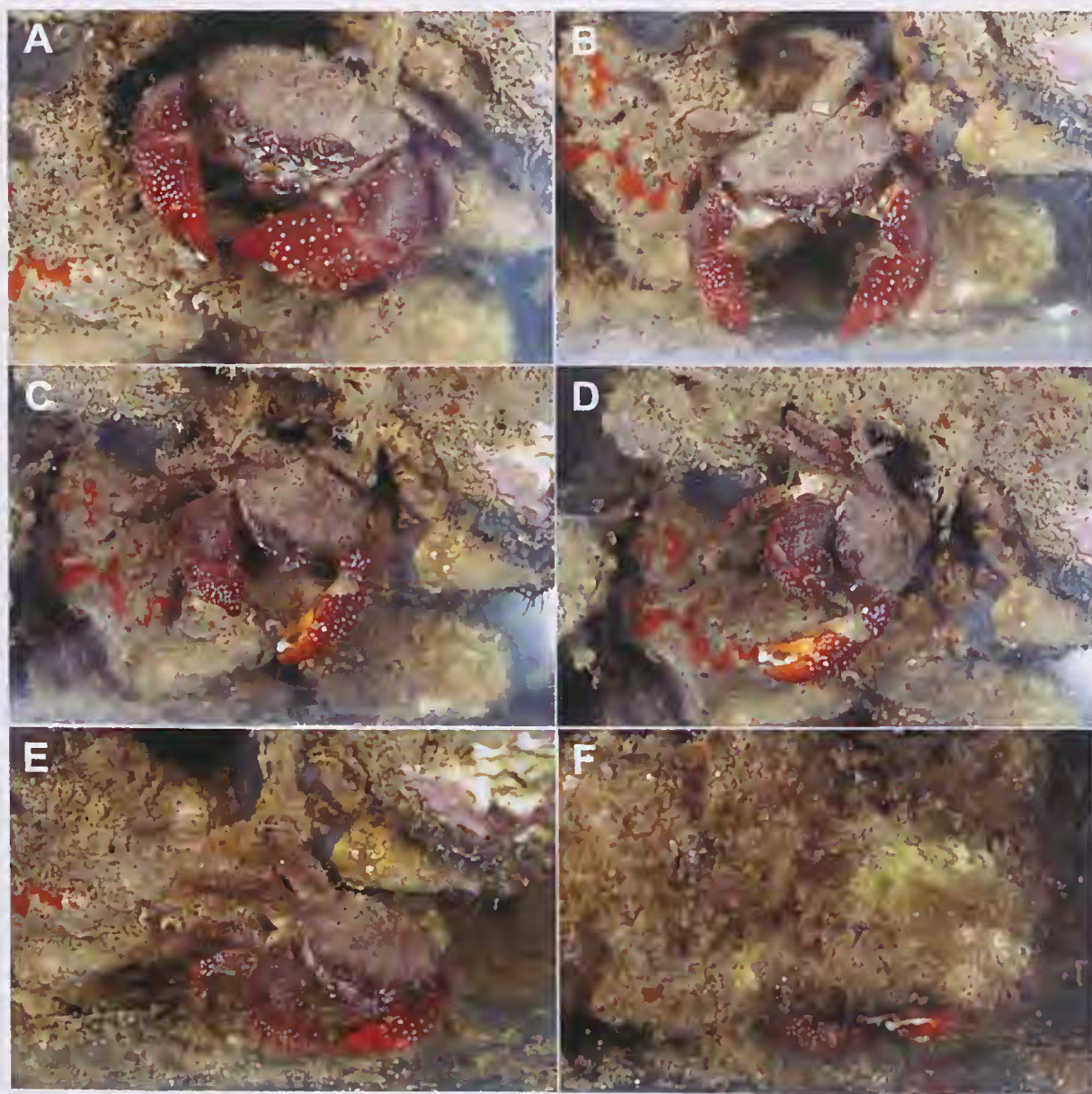


FIG. 3A-F. Sequence of pictures showing *Actumnus setifer* repositioning an upturned coral colony.

Lamberts & Garth 1977). This also seems to be true of *A. setifer*. Typical burrow morphology in a *Favia speciosa* colony consists of an entrance and feeding chamber on the underside of the colony (Figs 1E, 3, 4), a vertical shaft which opens to a habitation chamber, and small apertures to the upper (growth) surface of the coral colony. As many as 8-12 apertures may occur on a single colony 15-20 cm in diameter. Of 12 *A. setifer* inhabited colonies measured at

Green, Bird and Goat Islands wet weights ranged from 142g to 1106g, averaging 458g.

Crabs spent their time either at rest within the coral colony, feeding, or moving the colony. While at rest, crabs appeared to spend most of their time adjacent to the small apertures in the upper surface of the colony. This position is likely to facilitate respiration and detection of food. Feeding was usually undertaken in the large entrance chamber in the undersurface of

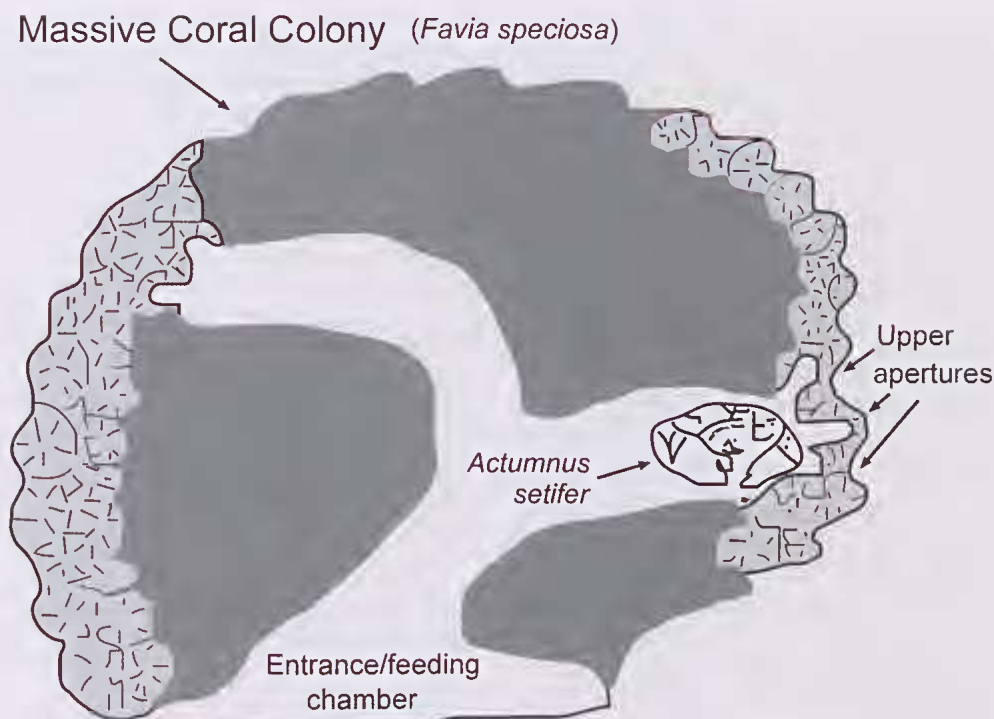


FIG. 4. Typical *Actumnus setifer* burrow morphology in a *Favia speciosa* colony.

the colony. Food was acquired by moving the colony over the top of the food, or occasionally by moving to the top of the colony and dragging the food item into the chamber. Even when obtaining food or righting the colony, crabs would seldom release their grip on the coral colony. This behaviour is identical for both sexes, and it would be interesting to know if female crabs release the first zoeae through the apertures in the upper surface, or whether they lift the colony clear of the substrate to facilitate more effective spawning.

SYMBIOSIS/MUTUALISM

While Lamberts & Garth (1977) and Marsh (1990) have referred to this type of coral-crab symbiosis as commensalism, we hesitate to use this term. Perhaps it is more a 'transportation mutualism' *sensu* Grutter & Irving (2007), similar to that of the Great Barrier Reef sipunculid *Aspidosi muelleri* that lives in a spiral cavity in solitary corals (Rice 1976). The sipunculid is protected under the coral which it moves around while it feeds, and the coral is kept upright on the substratum and transported to new feeding areas. This is essentially what Lamberts & Garth

(1977) suggested for the *Actumnus*/coral association. There is little formal evidence that transported corals have increased survival rates or growth benefits compared to attached corals, however one crab was observed to free itself, and the coral it lived in, from being completely buried in mud (I. Fellegara pers. observ.). Detrimental effects due to the presence of the crab have also been observed on a number of coral colonies. The formation of apertures requires the removal of some of the polyps and movement of the colony may result in tissue abrasion. Clearly this association is deserving of more study. As Grutter & Irving (2007) point out, 'positive interactions can play a fundamental role in maintaining the abundance and distribution of many marine species, as well as in structuring entire communities'.

CONCLUSION

Despite its widespread distribution throughout the Indo-West Pacific region and the general similarity of this distribution to that of hermatypic corals, *A. setifer* has not previously been reported as burrowing into, or carrying, coral

colonies. Similarly, although *F. speciosa* is also a widely distributed coral, overlapping in distribution with *A. setifer* throughout much of its range, no burrowing or carrying of this species by *Actinurus* crabs has been reported. An explanation for this lack of reporting may be that *Actinurus setifer* is locally less common in other areas, and because it is so well hidden within the coral clump, it has previously escaped attention. It may also simply be that because many small reef crabs, particularly those in the Pilumnidae and Xanthidae, occupy holes and crevices in rocks and coral, simply as places to hide, that the presence of *A. setifer* also in such shelters has been ignored as nothing unusual.

The central part of Moreton Bay appears to provide the perfect environment for this coral/crab association because of its low wave energy, numerous areas of sheltered coral patches dominated by small colonies of *Favia*, and the intervening areas of fine sediments with relatively little coarse coral debris. The *A. setifer*/*F. speciosa* association was found at every reef site which was searched with the exception of the dredged reef flat of Mud Island. The crabs absence at this site is attributed to the coral dredging method which left a residual deposit of mobile, coarse coral rubble covering the dredged substrate, thereby creating an unfavourable environment for these coral-carrying crabs.

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